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SPECIFICATION

TOOL FIXING DEVICE FOR A MACHINE TOOL SPINDLE

TECHNICAL FIELD

The present invention relates to a tool fixing device for a machine tool spindle, and more particularly to the provision of a gas spring for urging a draw bar to the tool fixing side on the outside of end surface of the spindle.

BACKGROUND OF THE INVENTION

A tool holding bore for holding tool is provided in an one end portion of the spindle of machine tool for machining a work, and the tool is releasably fixed to the tool holding bore by means of tool fixing device. Tool fixing device generally comprises a draw bar capable of being connected to the base of the tool, an urging mechanism for urging the draw bar to the tool fixing side (base side of the spindle), and a release mechanism capable of driving the draw bar to the tool release side (tip-end side of the spindle) against the urging force of the urging mechanism.

Various configurations of the urging mechanism for urging the draw bar to the tool fixing side have been proposed or are in practical use and, by way of example, the applicant of this application has previously proposed a tool fixing device that comprises an urging mechanism that urges the draw bar to the tool fixing side by the urging force of a gas spring in which a compression gas is sealed (Japanese Laid-Open Patent Application No. 2001-87910). In this tool fixing device, a draw bar extension part extending to the outside of the end face of the base of the spindle is

formed in a section at the base side of the draw bar, and a gas spring urges the draw bar at the draw bar extension part to the tool fixing side.

In addition, although a hydraulic cylinder for driving the draw bar to the tool release side against the urging force of the gas spring is also provided in the tool fixing device, this hydraulic cylinder is fixed to the housing of a spindle unit by way of a cover member that covers the gas spring, and the gas spring and the hydraulic cylinder are separately configured and not connected to each other.

Because the gas spring is provided outside the outer end surface of the base of the spindle and, unlike configurations in which the gas spring is assembled within the spindle, there is no need for the outer diameter of the cylinder main body that forms a gas actuation chamber to be smaller than the diameter of the spindle, the inner diameter of the cylinder main body can be enlarged affording a shortening of the overall length of the spindle unit configured from the spindle and the tool fixing device and so on. Furthermore, by virtue of the fact that the pressure-receiving surface area of a piston on which the urging force of the compression gas within the gas actuation chamber is also increased, even if the gas pressure within the gas actuation chamber is set low, a sufficient urging force for reliably fixing the tool can be adequately ensured.

It should be noted that gas pressure detection means capable of detecting a drop in gas pressure in the gas actuation chamber due to leak of compression gas is provided in the tool fixing device.

Next, a description will be made of the problems to be solved by the invention of this application.

Because the gas spring and the hydraulic cylinder of the tool fixing device of the abovementioned publication are provided separately and, accordingly, the gas

spring and hydraulic cylinder are not connected to each other, the gas spring and the hydraulic cylinder must be individually attached to the spindle unit including the spindle, and the assembly thereof takes time.

In addition, although in tool fixing devices in which a gas spring is assembled within the spindle the compression gas sealed in the gas actuation chamber must normally be maintained at a high pressure in order to reliably fix the tool to the tool holding bore, the higher the gas pressure the more likely it is that leak of the compression gas will occur. The tool cannot be fitted reliably and with the required high precision to the tool holding bore if the gas pressure in the gas actuation chamber drops below a prescribed pressure.

In this regard, the provision of the gas spring provided outside the outer end surface of the spindle of the tool fixing device of the abovementioned publication does, to some extent, alleviate the problems described above. However, even though a synthetic resin sealing member for preventing leak of compression gas from the gas actuation chamber is provided in the gas spring of the tool fixing device, the sealing of a high-pressure compression gas for a long period only by this sealing member is substantially impossible. In addition, although a technique has been proposed in which, in addition to the sealing member, a lubricating oil for lubricating the sliding part of the piston is employed to prevent the leak of compression gas, in this case as well, if the lubricating oil is not supplied in a sufficient amount to the periphery of the sealing member leak of compression gas cannot be prevented and the gas pressure drops in a short time. In addition, even though detection of a drop in gas pressure and replenishment of the compression gas is possible in the tool fixing device of the abovementioned publication, there is an increase in the frequency at which the replenishment of the compression gas occurs.

Furthermore, due to the heat that is generated during machining the temperature state of the spindle is quite high and, if a state in which there is very little dissipation of the heat transferred from the spindle to the gas spring continues an excessive rise in the gas pressure occurs due to the heat expansion of the compression gas resulting in an increase in the amount of compression gas leak, and the temperature of the lubricating oil rises resulting in a lowering of the viscosity thereof and a drop in the lubricating performance and the sealing performance of the lubricating oil.

The objects of the present invention include compacting of the configuration by connecting the gas spring and the fluid pressure cylinder and simplification of the assembly of the same on the spindle unit, suppression of drop in the urging force of the gas spring over a long period by as far as possible suppressing the leak of compression gas, and promotion of the dissipation of heat from the gas spring. Other objects of the present invention will be apparent from the descriptions of the embodiments of the present invention.

DISCLOSURE OF THE INVENTION

The tool fixing device for a machine tool spindle of the present invention for releasably fixing a tool mounted on an one end portion of the spindle of a machine tool, the tool fixing device comprising a draw bar capable of being connected to the tool, urging means for urging the draw bar to a tool fixing side, and release means capable of driving the draw bar to a tool release side against an urging force of the urging means, is characterized in that the draw bar is provided with a draw bar extension part extending to an outside of the other end face of the spindle, the urging means comprises a gas spring connected to the other end of the spindle so as to

rotate integrally therewith for urging the draw bar at the draw bar extension part to the tool fixing side, and the release means comprises a fluid pressure cylinder capable of driving the draw bar at the draw bar extension part to the tool release side, connected to an outer end of the gas cylinder.

In the state in which the tool is fixed to the spindle, the draw bar connected to the tool is forcibly urged at the draw bar extension part extending to the outside of the end face of the spindle to the tool fixing side by the gas spring of the urging means. The fixing of the tool is released when the draw bar is driven from this state by the fluid pressure cylinder of the release means to the tool release side against the urging force of the gas spring. In addition to the fluid pressure cylinder, the release means also comprises an actuating fluid supply source for supplying actuating fluid to the fluid pressure cylinder, and a connection hose for connecting the fluid pressure cylinder and the actuating fluid supply source.

Here, the fluid pressure cylinder is connected to the outer end of the gas spring. In other words, by virtue of the fact that the gas spring and the fluid pressure cylinder can be configured in one unit that is able to be assembled in advance, the urging means and the release means can be compacted and the assembly of the gas spring and the fluid pressure cylinder in the spindle unit including the spindle can be simplified.

Next, descriptions will be made for a preferable constitution of the present invention.

a) The gas cylinder and fluid pressure cylinder may be relatively rotatably connected. In this constitution, the fluid pressure cylinder is unrotatably fixed and only the gas spring integrally rotates with the spindle.

b) The gas spring comprises a cylinder main body externally fitted to the

draw bar extension part and connected to the other end of the spindle so as to rotate integrally therewith, a cylinder hole formed in the cylinder main body, a piston part integrally provided in a mid part of the draw bar extension part and mounted in the cylinder hole to be movable, and a gas actuation chamber formed in the spindle side of the cylinder hole with respect to the piston part and having a compression gas filled therein. Accordingly, the piston part is urged to the tool fixing side by the urging force of the compression gas in the gas actuation chamber that results in the fixing of the tool connected to the draw bar to the spindle.

c) The cylinder hole may be formed in a tapered shape of diameter decreasing to the spindle side. In this case, if a lubricating oil for lubricating between the piston part and the cylinder main body is injected into the gas actuation chamber, the lubricating oil attaches to the inner circumferential surface of the cylinder hole due to centrifugal force when the spindle and the cylinder main body rotate during machining and, furthermore, it moves along the tapered cylinder hole to be supplied to the sealing member mounted between the piston part and the cylinder main body.

Accordingly, because a lubricating oil is supplied to the sealing member at each rotation of the spindle, a reliable sealing is afforded between the piston part and the cylinder main body by means of the sealing member and the lubricating oil, the lifespan of the sealing member is increased because wear and sagging of the sealing member is suppressed, leak of compression gas from the gas actuation chamber can as far as possible be prevented for a long period, and the frequency at which the compression gas is replenished is also reduced.

d) The gas spring may comprise an urging member mounted in the gas actuation chamber for urging the piston part to the tool fixing side. In this case, because the draw bar extension part is urged to the tool fixing side by both the

urging force of the compression gas in the gas actuation chamber and the urging force of the urging member, if by some cause leak of the compression gas occurred resulting in a drop in the urging force produced by the compression gas, the tool would not drop out of the spindle during the rotation thereof because the fixed state of the tool can be maintained by the urging force of the urging member. In addition, by virtue of the fact that the gas pressure within the gas actuation chamber can be lowered to the extent that the urging member provides an urging force, leak of compression gas is unlikely to occur.

e) The cylinder main body may have a diameter substantially equal to or larger than that of the spindle. In this case, because the diameter of the gas actuation chamber of the cylinder main body can be further increased, the required volume of the gas can be ensured even if the length of the gas actuation chamber is shortened and the overall length of the main spindle unit including the spindle and the tool fixing device and so on can be shortened. In addition, by virtue of the fact that the gas pressure pressure-receiving surface area of the piston part can also be increased as a result of the increase in the diameter of the gas actuation chamber, the tool can be fixed firmly even when the gas pressure in the gas actuation chamber is low, and leak of compression gas from the gas actuation chamber is unlikely to occur.

f) The gas spring comprises a sealing member for sealing between the piston part and the cylinder main body, and a lubricating oil for lubricating between the piston part and the cylinder main body and for sealing the compression gas. In this case, because the sealing member and the lubricating oil provide a seal between the piston part and the cylinder main body, the leak of compression gas from the gas actuation chamber can as far as possible be suppressed.

g) The cylinder main body comprises filling ports for the filling in the gas actuation chamber with the compression gas and the lubricating oil. Accordingly, the filling in the gas actuation chamber with the compression gas and the lubricating oil can occur by way of the filling ports.

h) A fin for dissipating heat may be provided in the outer perimeter part of the cylinder main body. By the adoption of a constitution that affords a promotion of the dissipation of heat from the gas spring in this way, an increase in the amount of compression gas leak that occurs when the gas pressure rises excessively due to heat expansion of the compression gas that has its origin in the heat generated during machining can be prevented. Furthermore, a drop in viscosity of the lubricating oil due to a rise in temperature of the lubricating oil can be suppressed and, accordingly, a drop in the lubricating performance and sealing performance of the lubricating oil can as far as possible be suppressed.

i) Urging force detection means for detecting the urging force of the gas spring when the draw bar extension part is driven to the tool release side may be provided in the fluid pressure cylinder. Because the urging force of the gas spring when releasing the fixing of the tool can be detected each time the draw bar extension part is driven to the release side by the fluid pressure cylinder, whether or not a leak of the compression gas resulting in a drop in the urging force has occurred can be regularly checked prior to the initiation of machining and, accordingly, machining in a state in which the urging force produced by the compression gas has dropped can be prevented.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical cross section of a spindle unit (tool fixed state) of a

machine tool pertaining to an embodiment of the present invention;

FIG. 2 is a vertical cross section of the spindle unit (tool released state);

FIG. 3 is an expanded cross section of the urging mechanism and release mechanism (tool fixed state) of the spindle unit;

FIG. 4 is an expanded cross section of the urging mechanism and release mechanism (tool released state) of the spindle unit;

FIG. 5 is a diagram equivalent to FIG. 3 of a modification thereof; and

FIG. 6 is an expanded cross section of the urging mechanism and release mechanism of the spindle unit of another embodiment.

PREFERRED EMBODIMENT OF THE INVENTION

A description is given below of a best mode for carrying out the present invention.

This embodiment relates to one example of the present invention in a spindle unit of a vertical machining center. It should be noted that in the description given below the upper and lower and left and right of FIG. 1 are taken to mean the upper and lower and left and right of the device.

As shown in FIG. 1 and FIG. 2, a spindle unit 1 comprises a spindle 2, a housing 3 containing a drive motor 16 for rotationally driving the spindle 2, and a tool fixing device 4 for releasably fixing a tool 5 to an one end portion of a spindle 2. The tool fixing device 4 comprises a collet chuck 10 that engages with the top end of the tool 5, a draw bar 11 capable of being connected to the top end of the tool 5 by means of the collect chuck 10, an urging mechanism 12 for urging the draw bar 11 upward (tool fixing side), and a release mechanism 13 capable of driving the draw bar downward (release side) against the urging force of the urging mechanism 12.

A tapered tool holding bore 2a increasing in diameter toward the tip-end side is formed in a section of the lower end of the spindle 2, and a tapered shank part 5a formed in a base section of the tool 5 is able to engage with the tool holding bore 2a. The spindle 2 is arranged vertically in the housing 3, and by means of bearings 14, 15 both ends of the spindle 2 are rotatably supported by the housing 3. A drive motor 16 for rotationally driving the spindle 2 with respect to the housing 3 is assembled in a motor housing part 3a of the housing 3.

A tool holding bore 2a, and a housing hole 2b continuous with the upper end of the tool holding bore 2a, are formed in series in the inside of the spindle 2. The tool 5 comprises the shank part 5a capable of being internally fitted in the tool holding bore 2a, a small diameter shaft part 5b and engaging part 5c formed in the top of the shank part 5a, and a large diameter clasping part 5d formed in the tip-end side of the shank part 5a that is clasped by an automated tool changing device (not shown in the drawings) when the tool 5 is to be replaced. In the state in which the tool 5 is mounted on the spindle 2, the shank part 5a is engaged in a closely adhered state to the tool holding bore 2a, and the engaging part 5c is positioned in a state in which it faces the tip-end of the housing hole 2b.

Two cylinder members 20, 21 are internally assembled in the inner side of the housing hole 2b, and the collet chuck 10 is arranged in the inner side of the tip-end of the cylinder member 20. The collet chuck 10 clasps the engaging part 5c of the tool 5 by means of a plurality of partitioned collet bodies 10a.

The draw bar 11 is arranged in the cylinder members 20, 21 so as to slide in the vertical direction. The draw bar 11 comprises a draw bar main body 22 and a connecting body 23 fixed to the tip-end of the draw bar main body 22. A draw bar extension part 24 that extends to the outside of the top end face of the housing 3 and

the spindle 2 is formed in a top section the draw bar 11, and the urging mechanism 12 and release mechanism 13 are connected to the draw bar extension part 24. The lower end of the draw bar main body 22 is internally screw-fitted in the connecting body 23, and the collet chuck 10 and a spacer 25 engage to the connecting body 23 thereof.

In the state shown in FIG. 1 in which the draw bar 11 is urged upward by the urging mechanism 12, the collet chuck 10 is urged upward in a state in which it is clasping the engaging part 5c of the tool 5 and the tool 5 is fixed to the tool holding bore 2a. On the other hand, in the state shown in FIG. 2 in which the draw bar 11 is driven downward by the release mechanism 13, the collet chuck 10 is also moved downward producing the opened state of the collet partitioned bodies 10a and releasing the fixing of the tool 5.

A passage 22a through which a cutting liquid to be supplied to the tool 5 passes is formed in the interior of the draw bar main body 22, and a tip-end tube 26 that has through-connection to the passage 22a is provided in the interior of the connecting body 23. In the state in which the tool 5 is mounted in the tool holding bore 2a, the tip-end of the tip-end tube 26 pressure-contacts the engaging part 5c, and the cutting liquid from a cutting liquid supply device (not shown in the drawings) is supplied to the tool 5 by way of a rotary joint 27, the passage 22a and the tip-end tube 26.

Next, a description will be given of the urging mechanism 12.

As shown in FIG. 1 to FIG. 4, the urging mechanism 12 comprises a gas spring 30 that urges the draw bar 11 to the tool fixing side at the draw bar extension part 24. The gas spring 30 comprises a cylinder main body 31 externally mounted on the draw bar extension part 24 and screw-coupled to the top of the spindle 2 so as

to integrally rotate therewith, a cylinder hole 31a formed in the cylinder main body 31, a piston part 32 integrally provided in a mid part in the lengthwise direction of the draw bar extension part 24 and mounted in the cylinder hole 31a to be movable with a prescribed stroke, and a gas actuation chamber 33 formed in the lower side (spindle side) with respect to the piston part 32 of the cylinder hole 31a into which a compression gas 34 is filled.

The cylinder main body 31 is configured of a diameter approximately equal to that of the spindle 2, and the lower end of the cylinder main body 31 is screw-coupled to the spindle 2. A through hole 31b through which the draw bar extension part 24 passes is formed in the center section of the lower end of the cylinder main body 31. Two filling ports 31c for the filling of the compression gas 34 and lubricating oil are formed symmetrically in the left and right positions of the gas actuation chamber 33 at the lower end of the cylinder main body 31. When detaching the gas spring 30 from the spindle 2, the compression gas 34 is discharged through the filling ports 31c.

Furthermore, as shown in FIG. 3 and FIG. 4, a cylinder hole 31a connected to the upper end of the through hole 31b is formed in the cylinder main body 31 in a tapered shape decreasing in diameter toward the downward side (spindle side). A piston part 32 integrally formed with the draw bar extension part 24 is slidably mounted in the cylinder hole 31a. Synthetic resin sealing members 35, 36 are mounted between the cylinder hole 31a and the piston part 32 and between the through hole 31b and the draw bar extension part 24.

A high-pressure (for example, 3 to 7MPa) compression gas 34 (for example, compressed nitrogen gas) is filled in the gas actuation chamber 33, and the piston part 32 is urged upward by the compression gas 34. Here, because the cylinder

main body 31 is configured of a diameter approximately equal to that of the spindle 2, when compared to the internal assembly of the gas spring 30 is in the spindle 2, the diameter of the gas actuation chamber 33 formed in the cylinder main body 34 can be increased and the length of the cylinder main body 31 in the vertical direction can be shortened resulting in an overall shortening of the length of the spindle unit 1. In addition, by virtue of the fact that the pressure-receiving surface area of the piston part 32 can be enlarged, the required force for urging the tool 5 reliably can be ensured even if a slight lowering of the gas pressure of the compression gas 34 occurs, and leak of compression gas 34 from the gas actuation chamber 33 causing a lowering of gas pressure is unlikely to occur.

A lubricating oil 37 for lubricating between the draw bar extension part 24 and the cylinder main body 31 and for sealing the compression gas 34 is injected into the gas actuation chamber 33. Together with the sealing member 36, the lubricating oil 37, which is supplied naturally to the sealing member 36 between the draw bar extension part 24 and the through hole 31b by gravitational drip, affords a sealing between the draw bar extension part 24 and through hole 31b. Furthermore, because the cylinder hole 31a is formed in a tapered shape decreasing in diameter downward as described above, at high speed of rotation of the spindle 2 (for example, no less than 20,000 rpm) the lubricating oil 37 flows along the inner circumferential surface of the cylinder hole 31a due to centrifugal force due to the high speed of rotation and, furthermore, the lubricating oil 37 moves upward along the tapered cylinder hole 31a to be supplied to the sealing member 35 between the piston part 32 and the cylinder hole 31a and, the lubricating oil 37 lubricating between the piston part 32 and the cylinder main body 31, affords a sealing between the piston part 32 and the cylinder main body 31.

Next, a description will be made of the release mechanism 13.

As shown in FIG. 1 to FIG. 4, the release mechanism 13 comprises an hydraulic cylinder 40 that is relatively rotatably connected to the top end of the gas spring 30, and the gas spring 30 and the hydraulic cylinder 40 are configured in one unit able to be assembled in advance prior to assembly in the spindle unit 1. The hydraulic cylinder 40 comprises, for example, a cylinder main body 41, a piston member 42 which is the cylindrically-shaped piston member 42 being externally fitted slidably to a section on the upper side than the piston part 32 of the draw bar extension part 24, comprising a piston part 42a slidably mounted in the cylinder hole 41a in the cylinder main body 41, and an oil chamber 43 for driving the piston part 42a downward.

The cylinder main body 41 is relatively rotatably connected to the top end of the cylinder main body 31 of the gas spring 30 by a plurality of divided connecting bodies 44 divided in the circumferential direction. That is to say, although the gas spring 30 integrally rotates with the spindle 2, the hydraulic cylinder 40 does not rotate. An oil pressure supply port 41b for supplying pressurized oil to the oil chamber 43 is provided in the upper end of the cylinder main body 41. A position detection switch 45 for detecting the position of the draw bar 11 in the fixed state and the released state of the tool 5 is additionally provided in the upper end of the cylinder main body 41 and, on the other hand, a detection body 46 to be detected by the position detection switch 45 is provided on the piston member 42.

The cylinder piston member 42 is externally mounted to be both vertically and rotationally slidable with respect to the draw bar extension part 24. As shown in FIG. 3, in the state in which the piston part 32 of the gas spring 30 is in the upper limit position and the tool 5 is fixed to the tool holder 2a, the lower end of the piston

member 42 is disjoined from the upper end of the piston part 32. A loadcell 47 (urging force detection means) electrically connected to a control unit (not shown in the drawings) is provided in the lower end of the piston member 42 and, when the piston member 42 is driven downward by the hydraulic cylinder 40 when the draw bar extension part 24 is driven to the release side, as shown in FIG. 4, the upper end of the piston part 32 contacts the loadcell 47 and the loadcell 47 detects the urging force of the gas spring 30.

The oil chamber 43 is formed in the upper side than the piston part 42a and, when the pressurized oil is supplied to the oil chamber 43 from an oil pressure supply source (not shown in the drawing), the piston part 42a is driven downward and the lower end of the piston member 42 abuts the upper end of the piston part 32 resulting in driving the piston part 32 against the urging force of the compression gas 34. On the other hand, an air chamber 48 is formed in the lower side than the piston part 42a, and the air chamber 48 is connected to an air accumulator (not shown in the drawings) filled with a comparatively low-pressure pressurized air. Accordingly, the constitution is such that, in the state in which there is no pressurized oil supplied to the oil chamber 43 (tool fixed state), the piston part 42a is urged upward by the compressed air in the air chamber 48 and, when the gas spring 30 and the spindle 2 integrally rotate, the piston part 32 and piston member 42 do not contact.

Next, a description will be made of the operation of the tool fixing device 4.

First, as shown in FIG. 1, when pressurized oil is supplied to the oil chamber 43 of the hydraulic cylinder 40 in a state in which the draw bar 11 has been urged upward by the urging force of the compression gas 34 in the gas actuation chamber 33 resulting in the fixing of the tool 5 in the tool holding bore 2a, the piston member

42 is driven downward and, furthermore, the piston member 42 abuts the piston part 32 by way of the loadcell 47 and, against the urging force of the compression gas 34, the piston member 42 and piston part 32 are integrally driven downward resulting in driving of the draw bar 11 downward. When this happens the collet chuck 10 is also driven downward producing the opened state of the collet partitioned bodies 10a and resulting in the release of fixing of the tool 5 from the tool holding bore 2a (see FIG. 2). By virtue of the fact that the urging force of the gas spring 30 can be detected by the loadcell 47 at this time, the gas pressure state in the gas actuation chamber 33 can be detected.

Next, when the oil pressure of the oil chamber 43 is discharged following the mounting of a separate tool 5 is the tool holding bore 2a by the automated tool changing device, the tool 5 is firmly fixed to the tool holding bore 2a by the movement upward of the piston part 32 of the gas spring 30 by the urging force of the compression gas 34, the movement upward of the draw bar 11 and the collet chuck 10 afford clasping of the engaging part 5c of the tool 5 by the collet partitioned bodies 10a, and further movement upward of the draw bar 11.

When the spindle 2 is rotated at high speed to machine a work piece in this state, because the lubricating oil 37 in the gas actuation chamber 33 is urged to the inner circumferential surface of the cylinder hole 31a due to centrifugal force and, furthermore, because the lubricating oil 37 moves upward along the cylinder main body 31 formed in a downward tapered shape, the lubricating oil 37 is supplied to the sealing member 35 between the piston part and the cylinder member resulting in the reliable sealing between the piston part 32 and the cylinder main body 31 by the sealing member 35 and the lubricating oil 37. On the other hand, the lubricating oil 37 is also naturally supplied by gravitational drip to the sealing member 36

between the through hole 31b and the draw bar extension part 24 and this affords reliable sealing at the through hole 31b between the draw bar extension part 24 and the cylinder main body 31. It should be noted that because the lubricating oil 37 is quite viscous and, furthermore, once the lubricating oil 37 has been supplied between the cylinder hole 31a and the piston part 32, because the lubricating oil 37 is urged upward together with the sealing member 35 by the compression gas 34 in the gas actuation chamber 33, the lubricating oil 37 between the cylinder hole 31a and the piston part 32 is unlikely to drip downward and no essential drop in the sealing performance of the sealing member 35 occurs even when the spindle 2 is stopped.

The following advantages are afforded by the tool fixing device 4 as described above. By virtue of the fact that the hydraulic cylinder 40 is relatively rotatably connected to the top end of the gas spring 30 and is configured as one unit able to be assembled in advance prior to the assembly of the spindle unit 1, the urging mechanism 12 and the release mechanism 13 can be compactly configured and the assembly of the urging mechanism 12 and the release mechanism 13 in the spindle unit 1 can be simplified.

Because the lubricating oil 37 for lubricating between the draw bar extension part 24 and the cylinder main body 31 and for sealing the compression gas 34 is injected into the gas actuation chamber 33 and, furthermore, because the cylinder hole 31a is formed in a tapered shape decreasing in diameter downward, the lubricating oil 37 that flows along the inner circumferential surface of the cylinder hole 31a due to centrifugal force is supplied to the sealing member 35 along the tapered cylinder hole 31a. Accordingly, because the lubricating oil 37 is supplied to the sealing member 35 at each rotation of the spindle 2, a reliable sealing is afforded

between the piston part 32 and the cylinder main body 31 by the sealing member 35 and the lubricating oil 37 and, because the lifespan of the sealing member 35 can be increased because the wear and sagging of the sealing member is suppressed, leak of the compression gas 34 from the gas actuation chamber 33 can be prevented for a long period and the frequency at which the compression gas 34 is replenished is reduced.

By virtue of the fact that the cylinder main body 31 is configured of a diameter approximately equal to that of the spindle 2, the diameter of the gas actuation chamber 33 formed in the cylinder main body 31 can be enlarged and the length in the vertical direction of the cylinder main body 31 can be shortened resulting in an overall shortening of the length of the spindle unit 1. In addition, by virtue of the fact that the pressure-receiving surface area of the piston part 32 on which the urging force of the compression gas 34 acts can be enlarged, even if a slight lowering of gas pressure of the compression gas 34 occurs, the urging force required for reliably fixing the tool 5 can be ensured, and leak of compression gas 34 from the gas actuation chamber 33 due to lowered gas pressure is unlikely to occur.

Because the urging force of the gas spring 30 can be detected by the loadcell 47 each time the draw bar extension part 24 is driven to the release side by the hydraulic cylinder 40, whether or not leak of the compression gas 34 and a resulting drop in urging force has occurred can be regularly checked and machining in a state in which the urging force has dropped can be prevented.

Next, a description will be given of various altered modifications of the above embodiment. Identical reference numerals have been given to elements identical to those used in the above embodiment and, as is appropriate, the description thereof has been omitted.

1] As shown in FIG. 5, a heat dissipating fin 50 may be formed in a tool fixing device 4A in the outer perimeter part of a cylinder main body 31A of a gas spring 30A of an urging mechanism 12A. By the adoption of a constitution in which heat dissipation from the gas spring 30A is promoted in this way, excessive rise in gas pressure caused by heat expansion of the compression gas 34 due to the heat generated during machining which results in an increase in the amount of leak of the compression gas 34 can be prevented. Furthermore, a drop in viscosity of the lubricating oil 37 caused by the rise in temperature of the lubricating oil 37 can be suppressed which affords as far as possible the suppression of a drop in the lubricating performance and the sealing performance of the lubricating oil 37.

2] Where the generation of a larger urging force by the gas spring 30 is required, the cylinder main body 31 may be configured of a larger diameter than that of the spindle 2. In other words, the diameter of the cylinder main body 31 can be altered as appropriate in accordance with the urging force required for fixing the tool 5 to the tool holding bore 2a and the gas pressure of the injected compression gas 34.

3] The constitution may be such that, instead of the pressurized air of the hydraulic cylinder 40 being supplied to the air chamber 48, an urging member such as a coil spring or the like is provided, and the abutting of piston member 42 against the piston part 32 of the gas cylinder 30 during the rotation of the spindle 2 is prevented by the urging of the piston member 42 upward by the urging force of the urging member. Naturally, the supply of pressurized oil resulting in the drive of the piston member 42 upward by the oil pressure is possible.

4] Although the above embodiment of the present invention may have application in a spindle unit 1 of a vertical machining center, they may also have

application in a spindle unit 1 of a horizontal machining center. Because, in this case as well, the cylinder hole 31a is formed in a tapered shape of diameter decreasing to the spindle side, the lubricating oil 37 within the gas actuation chamber 33 is supplied to the sealing member 35 between the piston part 32 and the cylinder main body 31 during the rotation of the spindle 2 and the cylinder main body 31, and reliable sealing is afforded between the cylinder main body 31 and the piston part 32 by the sealing member 35 and the lubricating oil 37.

Next, a description will be given of another embodiment of the present invention.

As shown in FIG. 6, a tool holding device 4B comprises a draw bar 11B able to be connected to the top end of a tool, an urging mechanism 12B for urging the draw bar 11B upward (tool fixing side), and a drive mechanism 13B able to drive the draw bar 11B downward (release side) against the urging force of the urging mechanism 12B. A draw bar extension part 60 extending to the outside of the top end face of the spindle 2B is formed in a section of the top end of the draw bar 11B. The urging mechanism 12B comprises a gas spring 30B for urging the draw bar 11B downward. The drive mechanism 13B comprises an hydraulic cylinder 40B of a configuration substantially the same as that of the abovementioned embodiment, and the hydraulic cylinder 40B, which is connected to be relatively rotatable with the top end of the gas spring 30B by a plurality of connecting divided bodies 44B, can be configured as one unit with the gas spring 30B.

The gas spring 30B comprises a cylinder main body 31B externally fitted to the draw bar extension part 60 and fixedly-connected to the top end of the spindle 2B so as to rotate integrally therewith, a cylinder hole 61 formed in the cylinder main body 31B, a piston part 32B integrally provided in the lengthwise direction of the

draw bar extension part 60 and mounted in the cylinder hole 61 to be movable through a prescribed stroke, a gas actuation chamber 33B in which a compression gas 34 is filled and which is formed in the lower side (spindle side) than the piston part 32B of the cylinder hole 61, and a coil spring 62 (urging member) mounted in the gas actuation chamber 34B for urging the piston part 32B downward.

In the same way as the abovementioned embodiment mode, the cylinder hole 61 is formed in a tapered shape decreasing in diameter downward, and sealing members 35B, 36B are mounted between each of the cylinder hole 61 and the piston part 32B and between the through hole 63 through which the draw bar extension part 60 passes and the draw bar extension part 60. Furthermore, a lubricating oil 37 is injected into the gas actuation chamber 33B. The coil spring 62, which is externally mounted on the draw bar extension part 60 within the gas actuation chamber 33B, abuts an annular spring-receiving part 64 formed in the lower end of the piston part 32B that results in the urging of the piston part 32B upward.

In other words, the draw bar extension part 60 is urged upward by the urging force of the compression gas 34 in the gas actuation chamber 33B and the urging force of the coil spring 62. Accordingly, by virtue of the fact that even if the gas pressure in the gas actuation chamber 33B is comparatively low, the urging force required for reliably fixing the tool can be ensured and leak of compression gas 34 is unlikely to occur. In addition, by virtue of the fact that, if by some chance the urging force produced by the compression gas 34 were to drop because of leak of the compression gas 34, the tool can be maintained in the fixed state by the urging force of the coil spring 62, the tool will not fall out of the spindle 2B during machining and the like.

It should be noted that the number of coil springs 62 is not restricted to one

and the number of coil springs 62 can be altered, as appropriate, in accordance with the required urging force for fixing the tool reliably. Furthermore, instead of the coil spring 62, other urging means such as disk springs or the like can be employed.

The present invention is not restricted to the embodiment described above, and the present invention encompasses all devices to which a variety of alterations have been able to be made to these embodiment by a person skilled in the art that do not depart from the essence of the present invention.